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Spiders in Biological Control - An Australian Perspective

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Spiders in Biological Control - An Australian Perspective. - Spiders, and their potential as biological control agents, have been largely ignored in applied scientific research in Australia. Considerable research into the role of spiders in agricultural ecosystems has been conducted in U.S.A., Asia and Europe, allowing scientists there to concentrate on the benefits of particular spider species in biological control in agro-ecosystems. Spider numbers in the southern tropics are extremely high. Research into spiders as biological control agents in Australia is essential for the economic utilization of these abundant predators in the control of agricultural pests. Foreign research cannot be applied to Australian systems because species and conditions vary considerably.

Key-words: Araneae - Biological Control - Agro-ecosysems - Citrus - Australia.

INTRODUCTION

Spiders (Araneae) comprise a large, conspicuous component of the fauna in agro-ecosystems worldwide. About 40,000 spider species are known, and thousands more are unnamed; they are all predators which feed almost entirely on arthropods. Spiders play an important part in controlling pests in some agro-ecosystems (See reviews by RIECHERT & LOCKLEY 1984, YOUNG & LOCKLEY 1985, and NYFFELER & BENZ 1987). While some studies do not show one spider species to be effective in controlling insect pests, most show that a spider complex is successful in biological control.

Spider communities limit densities of pest populations (RIECHERT & LOCKLEY 1984), in cereal fields (NYFFELER & BENZ 1987), and orchards (MANSOUR *et al.* 1983). *Oxyopes salticus* Henz, contributes, in a predator complex, to the control of pest populations in cotton, and is more resistant to two widespread insecticides than are some target pests (YOUNG & LOCKLEY 1985). One spider species may not be able to control a single pest species, but spider assemblages can be effective in stabilising

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pest populations (PROVENCHER & RIECHERT 1994). As predators in a forest litter community, spiders have a strong stabilising effect on prey (CLARKE & GRANT 1968). Local prey abundance determines the degree to which a predator specialises. Most prey of two co-existing trapdoor spiders (Idiopidae and Nemesiidae) in Canberra are ants and beetles; these are also the most abundant potential prey items in the habitat (GREEN 1990). BISHOP (1980) also noted specialisation of spiders on the most abundant prey items in Queensland cotton fields.

MURDOCH *et al.* (1985) suggests that assemblages of predators limit the growth of pest populations. If predators are in a species assemblage which feeds on several prey species, and have population sizes limited by territoriality rather than by food, then they probably display "equilibrium point control" (RIECHERT 1990). Spiders fit this criterion as rarely does one species of spider occur in an ecosystem; they are polyphagous, and their population sizes appear limited by spatial aspects and cannibalism rather than by food (GREEN 1990; RIECHERT & LUCZAK 1982; RIECHERT & GILLESPIE 1986). In a study of a forest litter community, spiders were reported to have significant control of prey populations of collembolans and centipedes (CLARKE & GRANT 1968); and in agricultural systems spiders have been identified as part of a predator complex having a significant effect on insect pest numbers (see reviews).

SPIDERS AS PREDATORS OF ARTHROPOD EGGS

Spiders will eat arthropod eggs, but this is not widely known or accepted because spiders are considered to be predators of moving prey. Many *Cheiracanthium* spp. (Clubionidae) and *Latrodectus* spp. (Theridiidae) spiderlings consume fertile and infertile eggs in their own egg sacs (NYFFELER *et al.* 1990). Spiders also eat eggs of insect pests. A clubionid spider (*Cheiracanthium inclusum* Hentz), a salticid (*Phiddipus audax* Hentz), and thomisids (*Misumenops* spp.) consume *Helicoverpa virescens* (Fabricius) eggs (MCDANIEL & STERLING 1982). In Australia, *Cheiracanthium diversum* (Koch) eats *Helicoverpa* eggs in cotton fields (ROOM 1979); and *Cheiracanthium inclusum* was identified as a predator of velvetbean caterpillar eggs in Florida soybeans (BUSCHMAN *et al.* 1977). Spiders were observed consuming sugarcane borer eggs in Louisiana cane fields (NEGM & HENSLEY 1969). Egg predation was significantly higher at night than during the day; *Cheiracanthium* spp. are nocturnal hunters. A significant correlation exists between egg predation and spider numbers (NEGM & HENSLEY 1969).

AUGMENTATION

Specialist beneficial predators are commercially mass-reared and released. Spiders are considered unsuitable for this practice because of their non-specific prey preferences and cannibalistic behaviour. Clubionids (MARC 1993) and lycosids (THANG *et al.* 1989) have been successfully mass-reared in the laboratory. Commercial application may be possible in the near future. There are, however, other less costly augmentative methods to increase spider numbers in agricultural systems.

NYFFELER & BENZ (1987) suggest the effectiveness of spiders in biological control can be enhanced by augmentative methods other than mass rearing and release of beneficials. Intercropping is one method of increasing spider numbers and predation on pest species in agricultural systems. Careful investigation of suitable crops to interplant is warranted as some combinations do not appear to have an incremental effect on spider numbers. Intercropping soybean and maize increases spider abundance, but rice and soybean grown together have no effect on numbers of spiders (GYAWALI 1988). Tree crops, such as citrus, benefit from this method of augmentation, with flowers or weeds growing between rows (SMITH 1990). Selective weed control augments populations of beneficial predators and parasites. Under a weed cover of just 15-20%, the density of most of the arthropod taxa changed - increase of beneficials and decrease of pests - in sugarbeet fields (BOSCH 1987).

Intercropping flowers, in combination with mulching, enhances spider population numbers in mixed vegetable gardens (RIECHERT & BISHOP 1990). These techniques encourage spiders to remain in the area, rather than emigrate after or during harvesting. Mulch provided by mowing the cover crop of corn in Virginia provided a more favourable habitat for predators such as carabid beetles and lycosids (LAUB & LUNA, 1992). Mulching weeds is a common practice in citrus orchards to increase natural enemy populations (SMITH & PAPACEK 1993). Natural enemy augmentation is attained by planting earth banks (CHIVERTON 1989; THOMAS 1990), or hedges (BASEDOW 1990) in the middle of crop fields. Edge zones or boundary strips of natural habitat also increase natural enemy populations of which most are spiders (BASEDOW 1990; GALECKA 1966). Rice straw bundles arranged into cone shaped tents were effective refuges for arthropods in Philippine rice fields (SHEPARD *et al.* 1989). Several pest species colonise tents providing prey for beneficials of which spiders are the most abundant group. Such methods of augmentation as seen above have proved effective in increasing numbers of spiders in agricultural ecosystems and must be recommended.

THE AUSTRALIAN PERSPECTIVE

Research on spiders as potential biological control agents is considered valid by many researchers worldwide. In Australia, however, few studies have been carried out in this area. In the last thirty years, only about 5% of worldwide research into spiders as biological control agents has been conducted in Australian agricultural ecosystems.

The most extensive Australian study in this period, the role of spiders in cotton in south east Queensland, is that by BISHOP from 1973–1977 (See BISHOP 1980; BISHOP & BLOOD 1980, 1981). He found that the spider complex had a "continuous presence"; spatial coincidences occurred between spiders and pest insects; and some spider species aggregated in response to prey abundance. He proposes numerical responses of two species (*Cheiracanthium diversum* and *Oxyopes mundulus*). Numerical response, a density-dependent chacteristic of predators, is an increase in a predator population in response to an increase in prey density, and is achieved by aggregation and reproduction (WISE 1993). Reproductive numerical response occurs when predators put energy into producing more offspring than normal in response to increased prey. Peak numerical response of *Cheiracanthium* spiders in cotton occurred in April; spiderlings of this species normally leave the brood chamber in late Autumn (April in the southern hemisphere) and have a high survival rate (Main 1984). Reproductive numerical response is not accepted in this case, as *Cheiracanthium* species are univoltine (MAIN 1984). Additionally, no data indicate increased reproductive output, and emergence of spiderlings has merely coincided temporally with the peak population density of the pest insect.

Precipitin tests showed spiders to be chief predators of light brown apple moth in Australian Capital Territory; the leaf roller's defensive behaviour of violent wriggling makes them vulnerable to spider predation (MACLELLAN 1973). Spiders significantly reduced aphid numbers on irrigated grass pasture; although spiders were not as successful under high temperatures (DE BARRO 1992). BUCKLEY (1990) recommends maintaining an intact community of arachnid predators when designing integrated pest management for homopteran pests. Nocturnal spiders prey on eucalyptus sap-sucking eurymelid bugs when attendant ants are removed; ants consume the sugary exudate of the bugs (BUCKLEY 1990). The sensitivity of spider faunas is a valid consideration in deciding whether and how to use pesticides (BUCKLEY 1990). Some Australian studies give surveys of the arthropod population composition (including spiders) in varying agricultural ecosystems (DONDALE 1966; CANTRELL *et al.* 1983; EVANS 1985). Comprehensive surveys, to demonstrate the numerically dominant species in agro-ecosystems, are essential before conducting experiments on the predatory role and effectiveness of spiders.

SPIDERS IN TROPICAL ZONES

Studies surveyed support the hypothesis that a spider predator complex may suppress pest populations in agricultural ecosystems in temperate zones. However, more studies are needed to substantiate the story particularly in subtropical and tropical zones where there are more spider species, and presumably a larger predator complex. Most studies of spiders in agricultural systems have been in temperate zones. My study (Spiders in citrus in south east Queensland) is based in a sub-tropical zone of the southern hemisphere between 27° south and the equator. Few countries in the northern hemisphere, other than in Asia, lie in an equivalent area. Temperate zone research, while useful as reference material, has little or no bearing on the study at hand as far as spiders are concerned. Differences in species found in temperate zones and tropical zones are exemplified by the differences between spider numbers in North America and those of Australia. The spider fauna of North America comprises

3412 species plus about 230 undescribed species (PLATNICK 1991). Australia is smaller than the United States of America excluding Alaska, yet its spider fauna has been estimated at over 9,300 species (RAVEN 1988), 2,400 of which have been described. This suggests then that Australian spider species comprise a considerable percentage of the world total of 40,000 known species. PLATNICK (1991) also suggests that while biodiversity increases from temperate zones towards the equator, it also increases from north to south so that world biodiversity instead of being "egg-shaped" is actually "pear-shaped". From this estimate, spider species numbers and diversity are greater in Australia than in most other areas. Added diversity in a predator complex is just one reason for researchers in the southern tropics to accept that spiders have a role to play in biological control.

SPIDERS IN AUSTRALIAN CITRUS

Citrus is a perennial crop facilitating more stable spider populations which have no need to rely on immigration into orchards at the start of each spring when spiderlings disperse. Further, spiders experience minimal disruption from harvesting and ploughing. Plant diversity is low in orchard crops, but unit size is usually reasonably large, the climate is fairly stable, and plant populations are relatively permanent. Natural enemies are more likely to be effective in a stable than in an unstable environment. Greater success in biological control has been seen in orchard crop systems than in seasonal field crops (WAAGE & MILLS 1992). The role of spiders in citrus orchards has not been researched before in Australia or sub-tropical regions; although some research in temperate citrus has been conducted (MANSOUR *et al.* 1982, MANSOUR & WHITCOMB 1986, VAN DEN BERG *et al.* 1992, BREENE *et al.* 1993).

Surveys of arachnid fauna are essential before experimental work is carried out. I have sampled for spiders, using suction and pit trap methods, in South-east Queensland citrus orchards under varying management regimes (chemically sprayed, organic, and Integrated Pest Management (IPM)), different localities (coastal and inland), different fruit varieties (early and late picked), diurnally and nocturnally. This research will reveal the arachnid population composition, and more importantly, the numerically dominant species for later experimental research into spiders as potential biological control agents. Surveys of spiders conducted in northern hemisphere citrus cannot be assumed to reveal species similar to those in Australian orchards. The major genera in Queensland citrus orchards with those Queensland genera also seen in orchards of USA (Texas (BREENE *et al.* 1993), Florida (MANSOUR *et al.* 1982), and California (CARROLL 1980)), Israel (SHULOV 1938) and South Africa (VAN DEN BERG *et al.* 1987) are shown in Table 1. Differences are obvious in the composition of the arachnid populations in the various countries, with 53% of the Queensland genera not found in surveys in the temperate areas. Data for Queensland orchards are for Spring samples only, and presumably more diversity will be revealed in Summer and Autumn sampling when spiders are mature. Pit trap data have not been included.

TABLE 1

Spider genera found in Queensland citrus orchards showing those genera which are represented in orchards of other countries.

Family & Genus	Qld	Texas	Flor.	Calif.	Israel	S. Afr.
Amouribiidae, *Badumna* spp.	X					
Araneidae, *Araneus* spp.	X		X			X
Argiope spp.	X		X			
Argyrodes spp.	X		X		X	
Cyrtophora spp.	X					
Eriophora spp.	X	X	X			
Leucauge spp.	X		X			X
Ordgarius spp.	X					
Poecilopachys spp.	X					
Nephila spp.	X		X			
Clubionidae, *Cheiracanthium* spp.	X	X	X	X	X	
Clubiona spp.	X		X		X	
Ctenidae, *Thasyrhea* spp.	X					
Dictynidae, *Dictyna* spp.	X	X	X	X	X	
Hersiliidae, *Tamopsis* spp.	X					
Heteropodidae, *Heteropoda* spp.	X		X			
Oxyopidae, *Oxyopes* spp.	X	X	X	X		
Pisauridae, *Dolomedes* spp.	X					
Salticidae. *Cream* spp.	X					
Bavia spp.	X					
Lycidus spp.	X					
Maratus spp.	X					
Menamerus spp.	X				X	
Opisthoncus spp.	X					
Sandalodes spp.	X					
Servaea spp.	X					
Tetragnathidae, *Phonognatha* spp.	X					
Tetragnatha spp.	X	X	X	X	X	X
Theridiidae, *Achaearanea* spp.	X	X	X		X	
Thomisidae, *Bomis* spp.	X					
Diaea spp.	X					
Sidymella spp.	X					
Thomisus spp.	X				X	
Tmaris spp.	X				X	
Uloboridae, *Uloboris* spp.	X	X	X	X	X	
Zosos spp.	X					

DISCUSSION

Spiders may not fulfil the role of the classical biological control agent as they are generalist predators and have limited functional and numerical responses to population changes of specific prey species. However, spiders kill many more prey than they consume and such generalist predators can effectively control a complex assemblage of prey species rather than specific prey species. Such assemblages (of spiders), through their composite foraging activities, and spatial and temporal differences, can limit exponential growth of prey populations; but clearly, no single spider species can keep a prey population under control once an outbreak occurs. Community diversity must be maintained to maximise the number of predators and so the number of foraging styles. Spider populations are augmented by intercropping, mulching and reduced pecticide usage.

The generalist nature of spiders, in being able to maintain their population numbers through periods of low prey density, and their ability to take advantage of high prey densities, demonstrates their adaptability to most habitats. They are a stabilising influence in invertebrate communities and are usually present in fairly constant numbers. Predator complexes have more control over prey populations than single predators acting alone. Most mathematical models show that two competing species depress a prey population more than one predator acting alone (May & Hassell 1981).

Other benefits of a spider predator complex are that different spider species forage at different times of the day and night, resulting in constant foraging in a spider complex. When research is conducted into spider species for biological control, the whole complex must be investigated. Spiders are abundant in agro-ecosystems and, because pest species comprise a substantial part of their diets, they are important in limiting pest populations. Spider conservation and augmentation is essential in agricultural systems to enable chemical-free, or at least chemical-reduced pest management.

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